1,193,264

# PATENT SPECIFICATION

DRAWINGS ATTACHED

1,193,264

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COMPLETE SPECIFICATION

## Improvements relating to Bellows Devices

I, DINO EDWIN BOUSSO, an Israeli citizen, of 34 Aviv Street, Carmel, Haifa, Israel, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to devices for converting fluid pressure to angular movement or vice-versa.

According to the invention a device for converting fluid pressure to angular mechanical movement or vice-versa, the device comprises a hinge and end piece assembly comprising two end pieces and hinge means by which the end pieces are hinged together for relative angular movement, and at least one pouch between the end pieces formed entirely from flexible material and arranged to contain fluid under pressure and to enclose a chamber extending to a position adjacent to the hinge axis so as to define the shape of a wedge diverging in the radially outward direction relative to the axis of the hinge means when subjected to internal fluid pressure, the material of the pouch or pouches extending radially inwardly to a position adjacent the hinge axis and the walls of each pouch converging together and meeting at a radially innermost edge adjacent the hinge axis and being secured to the hinge and end piece assembly at said position along the entire length of said edge so as to restrain radial movement of the pouch or pouches relative to the axis of the hinge means.

By securing the radially innermost edge of each pouch along its entire length to the hinge and end piece assembly the transference of stress from the pouch to the hinge and end piece assembly is distributed uniformly along the whole length of the said innermost edge, with the avoidance of locaised stress concentrations which would tend to cause damage to the pouch in operation.

In this specification and in the appended claims, where reference is made to "rubber or plastics material" this term is intended to cover vulcanised natural or synthetic rubber, polyvinyl chloride, polyethylene, polyurethanes, polyamides or other natural or synthetic polymers suitable for use in the construction of flexible fluid-containing structures.

The term "hinge means" as used in this specification and in the appended claims is not limited to the common form of hinge in which a pair of rigid hinge members or plates are pivotally joined by a hinge pin but includes such alternatives as a flexible joint for example, a flexible spring or other means securing the end pieces to one another so as to permit relative angular displacement of the end pieces.

With the arrangement in accordance with the invention the normal advantages associated with bellows are available but with the additional feature of angular movement. Thus relative movement of the end pieces is associated with a change in volume of the pouch or pouches, but since the or each pouch is made of flexible material, it produces substantially no preloading and therefore no resistance to relative movement of the end pieces. The flexibility of the pouches enables them to be expanded to their full size by the fluid pressure and the pouch faces act as diaphragms or bulkheads which in the case of a multiple-pouch bellows construction tie the side walls of the pouches together at intervals and prevent the walls from bulging outwards away from one another.

Since the edges of the pouches, adjacent to the hinge axis, are positively located relatively to the hinge axis, the pouch faces forming the diaphragms then positively locate the radially outermost edges of the pouches at a fixed distance from the hinge axis and positively prevent the pouches from being squeezed radially outwards between the end pieces. Also, there is then no possible relative movement between

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the pouch end faces and the end pieces, or between adjacent pouch faces, and indeed these parts may be bonded together.

If the edges of each pouch other than that adjacent to the hinge axis are formed by a homogeneous continuity of material from one face of the pouch to the other, whereby when the pouch is expanded by fluid pressure, an uninterrupted curve is provided around these edges of the pouch, the tensile strength of the pouch material is utilised optimally and the optimum condition of stress distribution in the cell walls resulting from the fluid pressure is approached. This effect may be achieved by forming each pouch as a separate moulding having an open edge which is subsequently sealed and forms the edge of the pouch adjacent to the hinge axis. The open edge of the pouch may be heat sealed or otherwise bonded or it may alternatively or in addition be clamped between a hinge plate and one end piece.

In an alternative construction, the or a number of the pouches, and possibly also the hinge and even the end pieces, are formed by an integral extrusion, the extrusion direction being parallel to the hinge axis, after which the edges of the pouches extending radially from the hinge axis of the device are sealed. This enables a bellows of any suitable length, in a direction parallel to the hinge axis, to be prepared by cutting a suitable length off the extrusion.

The device has a high energy transfer "weight of material" ratio and has a wide range of uses and sizes. For example it may be used as an angular actuator by supplying fluid pressure to the pouches so that the end pieces are forced apart. Such an actuator may be used in applications as widely varied as the provision of one degree of rotation at a joint in an artificial limb or to the provision of the torque necessary to raise the back of a tipping lorry. Two or more of the pouches may be used in a push-pull relationship, for example to open and/or close end pieces forming the arms of a scissors. The pouches will then be appropriately positioned in the angles between the arms around the scissors axis and will be expanded as necessary.

Rather than be used as a conventional actuator, the device may alternatively be used to pump fluid which is drawn into and expelled from the bellows through appropriately valved ducting, as the end pieces are mechanically moved apart and together respectively. This use of the device can provide a leakproof pump with no fluid to metal contact. Another use of the device is to absorb momentum, in the manner of a shock absorber or spring.

When used as a shock absorber, the device may have a sealed bellows, the pouches of which have extensible walls and are filled with a viscous fluid. The energy which is transmitted to the fluid through relative movement of the end pieces towards one another is then absorbed by the internal friction of the fluid. Alternatively with inextensible walls, a throttling valve may be installed at the inlet which connects to a chamber into which the expelled fluid is directed. Various gas-liquid combinations are possible to suit different requirements.

The effect of a spring could be obtained by using a low viscosity fluid together with resilient walls or by using a gas or gas-liquid combination together with more or less inextensible walls. By using various combinations, different degrees of damping and springiness can be achieved. The device may also be used as part of a vehicle suspension in which fluid presssure is developed by relative movement between the suspension parts at one corner of the vehicle, and transmitted to another corner to produce a counterbalancing of relative movement between other suspension parts.

When fluid is supplied to or expelled from the pouches, it may flow to and from the pouches through separate ducts leading into the pouches but preferably a common duct, for example provided through one of the end pieces, is provided to the interiors of the pouches which are all in communication with one another in the manner of a conventional bellows. For this purpose the contiguous faces of adjacent pouches will be sealed together, at least around an aperture through which the pouches are in communication with one another.

Three examples of devices constructed in accordance with the invention are illustrated in the accompanying drawings, in which: —

Figure 1 is a diagrammatic perspective view of the first example with parts broken away in section;

Figure 2 is a diagrammatic perspective view showing one method of pouch construction;

Figure 3 is a diagrammatic radial section through a second example, and

Figure 4 is a diagrammatic radial section through a third example.

The device illustrated in Figure 1 is in the form of an actuator consisting of metal end plates 1 and 2, forming the end pieces, which are joined together by means of a metal hinge 3 to form a hinge and end piece assembly, hinge plates 4 and 5 being respectively screwed by screws 6 to the edges of the plates 1 and 2.

In this example the bellows between the end plates 1 and 2 consists of four pouches 7 which are each formed from natural or synthetic cord fabric, coated and impregnated with a plastics material or rubber. The radially outermost and radially extending edges of the pouches are each formed as a continuous homogeneous curve as the radially innermost edges of the pouches are moulded open but subsequently sealed with bonding material and clamped, two between the hinge plate 4 and the end plate

1, and the other two between the hinge plate 5 and end plate 2. The side faces of each pouch are parallel when moulded but the pouch is constrained to a wedge shape when pressurised because of the edges which are clamped adjacent to the hinge 3.

It will be noted that the end plates 1 and 2 contact and extend beyond the whole of the radially extending portions of the sides of the adjacent pouches, and the arrangement is such that in the inflated condition the radially outermost end of the pouch or each pouch does not extend circumferentially beyond the sector-shaped cross-sectional region defined by the radially-extending inside surfaces of the end plates.

The adjacent faces of the pouches 7 are bonded together over an annular area 8 surrounding a hole 9 through which the cell formed by the interior of one pouch is in communication with the cell formed by the interior of the next pouch. The pouch face contiguous with the end plate 1, is bonded to the end plate and is additionally clamped by a flange 10 on a screw threaded tubular spigot 11 which leads through the end plate 1 into the interior of the first bellows pouch, and hence into the interior of all the pouches which are in communication with one another through the holes 9. If desired a similar spigot 11 may be provided through the other end plate 2 into the other end pouch 7.

Instead of providing the tubular spigot 11, and the holes 9, fluid may be supplied to and expelled from the pouches 7, through separate flexible hoses 12 one leading into a corner of each of the pouches 7, as suggested in chain dotted lines. In this case the adjacent faces of the pouches need not be bonded together.

If the device is to be used as a rotary actuator at the joint in an artificial limb, such as an elbow joint, the end plate 1 will be rigidly fixed to the artificial upper arm and the end plate 2 to the artificial forearm. When fluid under pressure, such as compressed air, or oil from a hydraulic pump, is then fed to the interior of the bellows through the duct 11 or hoses 12, the pouches will be expanded and the bellows extended so that the plates 1 and 2 are swung apart to bend the elbow. The limb is subsequently straightened again by releasing the fluid pressure to the bellows and providing a return spring to urge the plates 1 and 2 together again as the bellows collapses.

If the device is to be used as a pump, the oil or other fluid may be drawn into the bellows through the spigot 11 or hoses 12 as the plates 1 and 2 are mechanically opened, and subsequently expelled from the bellows as the plates 1 and 2 are closed, either through the same spigot 11, or through the similar spigot extending through the plate 2, or through the hoses 12, depending upon the ducting and valve arrangement provided.

If the device is to be used as a shock absorber or spring, the bellows will be filled with fluid through the spigot 11 or hoses 12 which will then be sealed with a screw cap or other closure. The mechanical reaction urging the plates 1 and 2 together, can then be absorbed by internal friction in the fluid or resilient extension of the pouch walls. Alternatively, with inextensible walls, the fluid will be expelled through a throttling valve into a suitable container.

Figure 2 shows a preferred form of pouch construction. The pouch 20 comprises an inner lining 21 formed from relatively impermeable material such as Butyl rubber or Nitrile rubber (for resistance to certain types of mineral oil). The lining 21 is formed first, by known methods, and is provided with a grommet 22 which will, in the assembled bellows, provide communication between adjacent pouches. The grommet 22 is bonded at one end to the lining 21, the other end projecting from the pouch 20 for bonding to the lining of the adjacent pouch in the assembled bellows.

The inner lining 21 is then covered by two layers 23 and 24 of rubberised parallel-cord fabric, the cords in the layer 23 lying at right angles to the hinge axis in the assembled bellows while the cords in the layer 24 lie parallel to the hinge axis. The layers 23 and 24 are built up around the inner lining 21 by normal fabricating methods as used for example in tyre building and are moulded and vulcanised in the known manner, additional reinforcing patches being provided at the corners of the pouch if necessary. The cords from which the layers 23 and 24 are made may be of any suitable material such as rayon, nylon, steel wire or glass fibre.

Where the bellows is to be used with higher fluid pressures in excess of 100 pounds per square inch it may be desirable to keep the inner lining separate from the reinforcement layers 23 and 24 in the finished pouch, but it may alternatively be bonded to the inner surface of the layer 23. For lower pressures, a pouch made from an unreinforced rubber or plastics material, or a dip-moulded pouch reinforced with woven fabric may be used.

The device illustrated in Figure 3 is extruded from thermoplastic material, the extrusion providing pouches 7*a*, blocks 1*a* and 2*a* forming the end pieces, and a hinge 3*a* formed by the film of material joining the blocks 1*a* and 2*a*, the pouches and the hinge and end piece assembly thus constituting an integral unit. The extrusion is cut to the required axial length and the radially extending edges of the extrusion are then sealed. This is accomplished by separating the pouches at the edges and then bonding them together by heat or using some other technique.

The pouches alone may be extruded and the end pieces may be separate parts which are hinged together and between which the extruded pouches are located.

If this device is to be used as a shock absorber, the pouches will be filled with fluid and then sealed. Alternatively permanent ducting for fluid into and out of the pouches may be provided either separately by using hoses such as the hoses 12 shown in Figure 1, or by common ducts extending through one or other of the blocks 1*a* or 2*a*. In this case the extrusion will be pierced to provide the ducts through the blocks and the common end faces of the pouches, which provide the radially extending diaphragms, will be pierced at the same time so that the interiors of all the pouches are in communication with one another.

Figure 4 shows one arrangement of a device 30 in accordance with the invention which is capable of providing a push-pull action.

The device 30 comprises a pair of bellows 31 and 32 arranged on opposite sides of a hinge comprising hinge plates 33 and 34 and a hinge pin 35. The pouches 36,37 which form the bellows 31,32 are clamped at their radially inner edges between triangular-section end pieces 38,39,40,41 and the hinge plates 33,34, which constitute a hinge and end piece assembly, by screws 42,43.

The device 30 is in the form of a scissors arrangement, in which the end pieces and hinge plates can be moved angularly relative to one another in either direction by supplying fluid pressure through connections (not shown) to an appropriate bellows.

WHAT WE CLAIM IS:—

1. A device for converting fluid pressure to angular mechanical movement or vice-versa, the device comprising a hinge and end piece assembly comprising two end pieces and hinge means by which the end pieces are hinged together for relative angular movement, and at least one pouch between the end pieces formed entirely from flexible material and arranged to contain fluid under pressure and to enclose a chamber extending to a position adjacent to the hinge axis so as to define the shape of a wedge diverging in the radially outward direction relative to the axis of the hinge means when subjected to internal fluid pressure, the material of the pouch or pouches extending radially inwardly to a position adjacent the hinge axis and the walls of each pouch converging together and meeting at a radially innermost edge adjacent the hinge axis and being secured to the hinge and end piece assembly at said position along the entire length of said edge so as to restrain radial movement of the pouch or pouches relative to the axis of the hinge means.

2. A device according to claim 1 wherein the or each pouch is formed from rubber or plastics material.

3. A device according to claim 2 wherein the or each pouch is formed from rubber or plastics material comprising a cord reinforcement.

4. A device according to claim 3 wherein the or each pouch is formed from two or more layers of rubber or plastics material each of which comprise a cord reinforcement in which the cords lie parallel to one another, the cords in one layer being disposed in a different direction relative to the cords in another layer.

5. A device according to claim 4 wherein the cords in one layer are disposed substantially at right angles to the axis of the hinge means and the cords in the other layer are disposed substantially parallel to the axis of the hinge means.

6. A device according to any of claims 3—5 wherein the or each pouch comprises an inner lining of relatively impermeable material together with at least one outer layer of rubber or plastics material comprising a cord reinforcement.

7. A device according to claim 3 wherein the or each pouch is formed by dip-moulding.

8. A device according to any of claims 3—7 wherein the or each pouch comprises a woven fabric reinforcement.

9. A device according to any of the preceding claims wherein one edge of the pouch or pouches is clamped between a hinge plate of the hinge means and one end piece so as to lie parallel to and closely adjacent the hinge axis.

10. A device according to any of the preceding claims wherein the edges of the or each pouch other than that adjacent the axis of the hinge means are formed so as to provide an uninterrupted curve around these edges when the or each pouch os expanded by fluid pressure.

11. A device according to any of the preceding claims wherein two or more pouches are provided, means being provided for enabling fluid pressure to be supplied to each pouch.

12. A device according to claim 11, adjacent pouches having an opening in their contiguous faces to provide communication between the pouches.

13. A device according to claim 12 wherein the aperture is formed in a grommet sealed to each of the adjacent pouches.

14. A device according to claim 13 wherein the adjacent pouches each comprise an inner lining of relatively impermeable material and wherein the grommet is sealed to the inner linings of the adjacent pouches.

15. A device according to any of claims 12—14 wherein a duct is provided through one of the end pieces for the supply of fluid to, or the withdrawal of fluid from, the interior of all the pouches.

16. A device according to claim 1 or claim 2 wherein the pouch or a number of the pouches are formed by an integral extrusion, the extruded direction being parallel to the axis of the hinge means, the extreme edges of the pouches extending radially from the hinge axis being sealed.

17. A device according to claim 16 wherein the integral extrusion also includes the hinge means.

18. A device according to any of the preceding claims wherein at least two pouches are arranged on opposite sides of the hinge means so as to be disposed between the end pieces on opposite sides thereof in a scissors arrangement, whereby the end pieces can be moved angularly relative to one another in either direction by fluid pressure supplied to an appropriate pouch.

19. A device according to claim 1 wherein the material of the pouch is secured to the hinge and end piece assembly by clamping the flexible material between relatively rigid components adjacent the hinge axis.

20. A device according to claim 1 wherein the end pieces are arranged so that in the inflated condition the radially outermost end of the pouch or each pouch does not extend circumferentially beyond the sector shaped cross-sectional region defined by the radially extending inside surfaces of the end pieces.

21. A device for converting fluid pressure to angular mechanical movement or vice-versa constructed and arranged substantially as described herein and illustrated in Figure 1 of the accompanying drawings.

22. A device for converting fluid pressure to angular movement or vice-versa constructed and arranged substantially as described herein and illustrated in Figure 1 of the accompanying drawings and incorporating the pouch construction illustrated in Figure 2 of the accompanying drawings.

23. A device for converting fluid pressure to angular mechanical movement or vice-versa constructed and arranged substantially as described herein and illustrated in Figure 3 of the accompanying drawings.

24. A device for converting fluid pressure to angular mechanical movement or vice-versa constructed and arranged substantially as described herein and illustrated in Figure 4 of the accompanying drawings.

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Sheet 1

FIG. 1

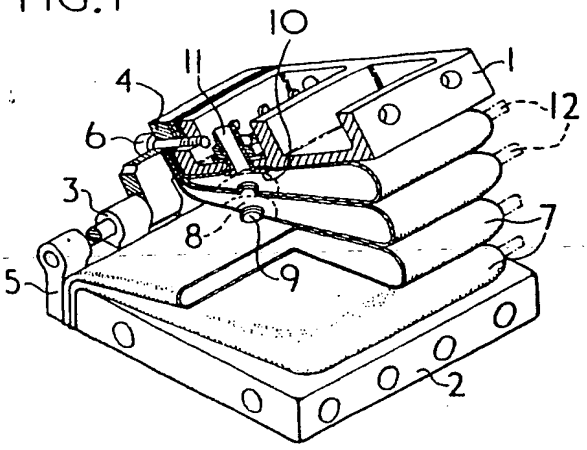
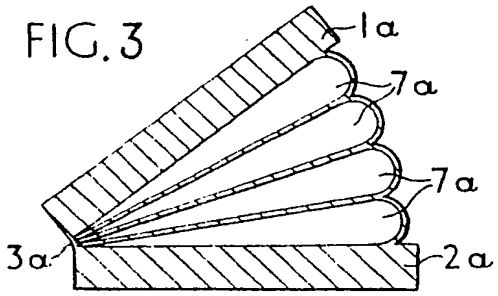



FIG. 3



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Sheet 2

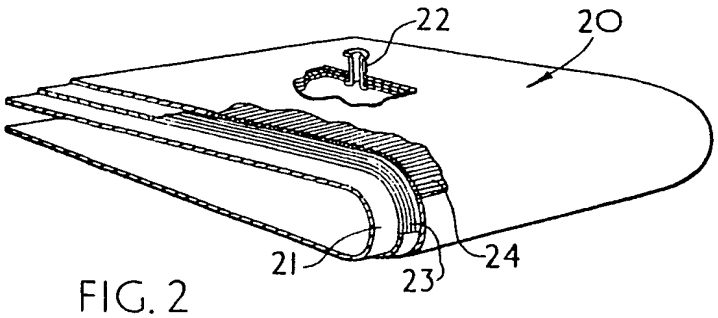


FIG. 2

FIG. 4